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ABSTRACT

This system for predicting enrollment in the London Borough of Bromley was first developed for the Hertfordshire County Council and was modified to fit the unique situation in Bromley, including high mobility of the population and high proportion of children in private schools. The system divides the borough into 207 zones and produces forecasts for each zone for each of the next seven years. The forecasts show the age of each pupil, sex, and whether Roman Catholic. To make predictions, information is collected and analyzed on housing development in the area, immigration into new houses, migration of the population, and private school children. Additional forecasts are made of children outside the borough who may need places in schools within the borough. Each year the system and forecasts are updated. The main features of the forecasting system and the procedures involved in applying it are described. (Author/JM)

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P. J. Smith

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SUMMARY

This report for Bromley Education Department describes the operational system for predicting pupil populations in the London Borough of Bromley. The Local Government Operational Research Unit formulated a basic approach to this problem in the Hertfordshire County Council project, and this has been used in several more recent pupil forecasting studies for other local authorities.

The details of the method have been modified to cater for problems specific to Bromley - for example, the high mobility of the population and the high proportion of children going to private schools.

The borough has been divided into some 200 'zones', and the method predicts in detail, for each zone, the number of boys and girls of each age who will require education for each year, up to seven years ahead. Each year the system is updated with the latest information and new forecasts are made.

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1 - INTRODUCTION

Each year Bromley education department, in common with local education authorities throughout the country, is faced with the task of reviewing its school building programme. To carry out the review it needs to know how many pupils of each age, sex and religion there will be in future years, and whether or not these will go to local authority or private schools. In addition, so that any school development is carried out in the place where it is most needed, the education department needs to know the geographical distribution of these pupils over the local authority area. To allow sufficient time for the planning and building of schools, forecasts are usually required for several years ahead.

The London Borough of Bromley asked the Unit to adapt the forecasting system first developed for Hertfordshire County Council to the particular requirements of the borough. The system that was designed divides the borough into 207 zones and produces forecasts for each zone for each of the coming seven years. The forecasts show in detail the ages of the pupils (0 - 18 years), their sex, and whether or not they are Roman Catholic.

To make the predictions, information is collected and analysed on (1) housing development in the area, (2) child inmigration into new houses, (3) migration of the population, (4) school leavers, (5) new births, (6) Roman Catholic child population, and (7) private school children. Additional 'external zone', forecasts are made of the number of children from outside the borough who may require places in schools within the borough.

This report describes briefly the main features of the forecasting system and the procedures involved in applying it. There are three main sections:

1. Setting up the forecasting system
2. Making the forecast
3. Updating the system

A final section discusses the special program to deal with the external zones.

* * * * *

In a forecasting project of this type the organisation and collection of data requires the major amount of effort rather than the development of complicated techniques; although over 100,000 individual forecasts are produced each year, the computer carries out relatively simple calculating operations. The setting up of an accurate information system is therefore of paramount importance. At present, the data retrieval system that is proposed is based on the existing manual filing of the relevant records in the borough. However, this could be relatively easily modified to computer based filing if required.

2 - SETTING UP THE FORECASTING SYSTEM

Three preliminary steps must be taken before the forecasting system can be put into operation.

1. Define the data base available within the area concerned. The data collected must relate to some fixed reference grid. The zones chosen are combinations of Census Enumeration Districts expected on average to produce half a form's entry of children per year. The first step therefore is to compile a street index showing the zone in which each address falls.

2. Collect information for each zone on (1) the base population, (2) inmigration and outmigration, (3) Roman Catholics, and (4) children moving into new houses.

   Once this step has been completed, a suitable forecasting model can be designed to fit the information that is available, and a computer program prepared.

3. Use the information that has been collected to get as accurate a picture as possible of the initial figures from which to make the forecast. This step is carried out automatically by the computer. This finds the underlying trends in the data and uses them to predict the likely situation in the future. The particular procedures involved concern: (1) births as a proportion of 1 year old children, (2) Roman Catholic baptisms as a proportion of births, (3) net migration as a proportion of base population, and (4) external zones populations.

3 - MAKING THE FORECAST

Forecasts are made in two stages: a forecast for one year ahead, and a forecast for subsequent years. The first two sections outline the steps involved in each stage and a final section discusses in more detail the procedures included in the computer program.

STEPS INVOLVED IN FORECASTING ONE YEAR AHEAD

The procedures involved in making the forecast are the same in each zone, although the basic data and final results are specific to a single zone. A full description of the steps in making the forecast for a zone is shown in Figure 1, and a brief outline is given below. This refers to boys only, but exactly the same process is followed to predict future numbers of girls.

There are ten steps:

1. Find the base population in yearly age groups (A). This should normally be the lastest available figures, and will be divided into two groups according to age:
   a. 0-4: all boys resident in the zone
   b. 5-18: all boys resident in the zone and attending an L.E.A. School.

2. Age the population by one year to give an aged base (C)

3. Generate new inmigrant children of all ages by feeding new house predictions for the year into the child/house type relationship. The split between boys and girls is that of the existing split of the base population in the zone.

4. Add the number of boys expected to come into new houses to the base to form a revised base population.

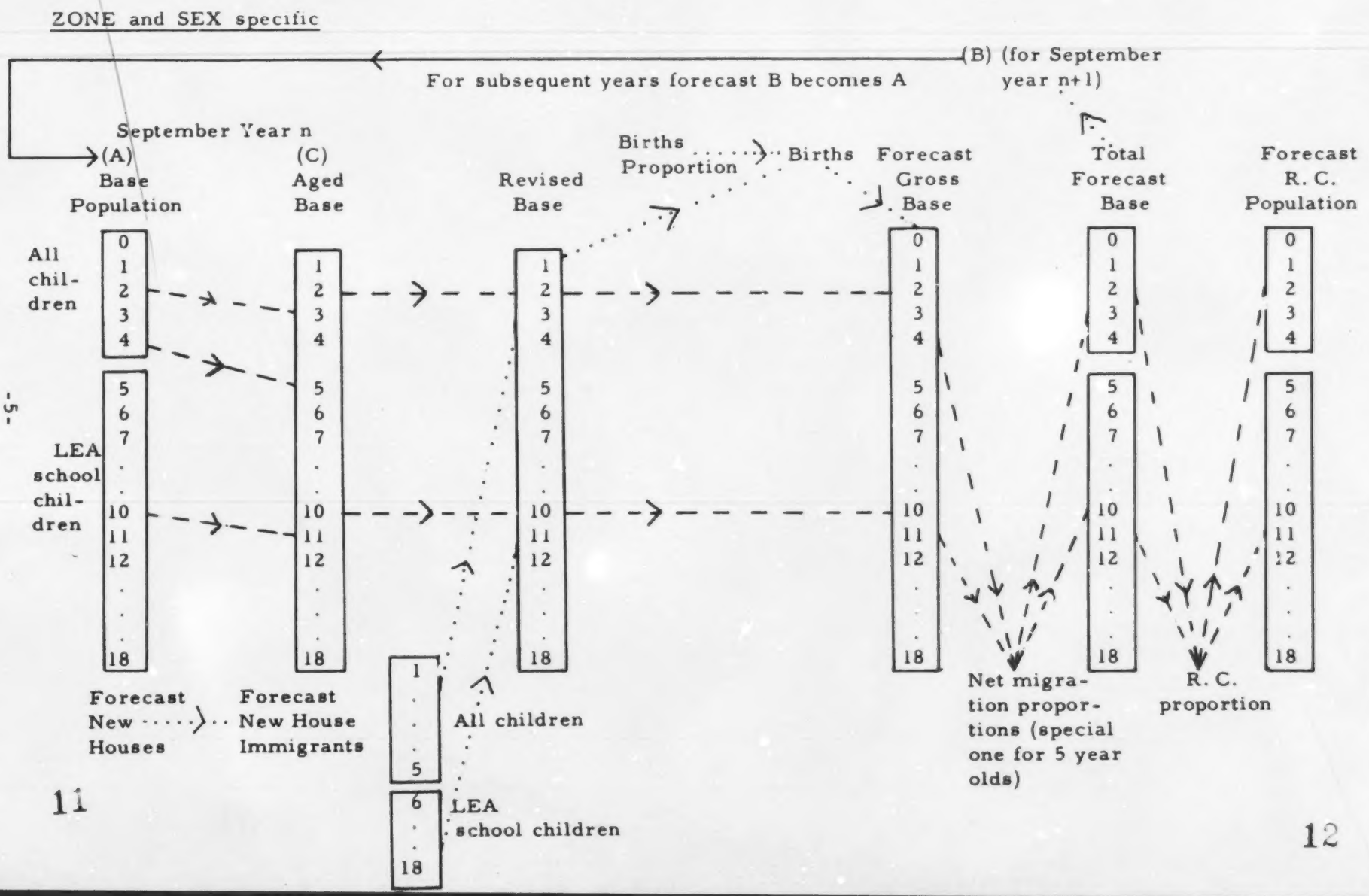
5. Forecast the child births proportion for the zone and apply it to the revised base to give the number of births. The split between sexes is taken as the split of last year's boy and girl births over all the Borough.

6. Add the boy births to the base.

7. Forecast the net migration proportion and multiply it by the new gross base to give net migration.

FORECASTING N PERIODS AHEAD

Figure 1



8. Add the boy net migration to give the total forecast base population (B).

9. Forecast the Roman Catholic proportion.

10. Match the zone to the parish and apply the Roman Catholic proportions to the ages. Calculate the Roman Catholic base.

STEPS INVOLVED IN FORECASTING FOR SUBSEQUENT YEARS

Once the forecast for one year ahead has been made, the total forecast base population (B) becomes the new base population and the same procedures are repeated. However, certain procedures recalculate their parameters (or variables) from year to year. These are:

1. Births proportion - a new births proportion is calculated each year using the 'Clark-Davies' exponentially smoothing procedure (see Appendix 3 for a brief explanation of this method).

2. Net migration proportion - if new houses were built in the previous year and their house migration proportion (i.e. 'newish' house proportion) differs from the overall migration proportion, then the latter is adjusted to take into account the effect on migration of the new houses.

3. Roman Catholic births proportion - a new proportion is calculated each year using the 'Clark-Davies' method.

4. Roman Catholic proportion - the Roman Catholic proportion is changed each year in such a way that the new proportion for j year olds is the previous year's proportion for j-1 year olds.

A more detailed description of these procedures and the recalculation process is included in the next section.

PROCEDURES IN THE METHOD

At the start of the forecasting cycle, the information contained in the computer within each cell - which is defined by zone, year of forecast, and individual age band - is (1) total child

population, (2) proportion of boys, and (3) proportion of Roman Catholics.

Taking this information as its starting point, the program goes through several mathematical procedures (or routines). These procedures differ in the amount of detail their predictions take into account - i.e., the births proportion predicts only the number of children, not boy or girl births individually; and the net migration proportion predicts migration of boys and girls separately, but only in age groups.

There are four procedures, which refer to:

1. Child/House-type relationships (age specific). New houses mean new inmigrant children causing a permanent increase in pupils to be educated in that area. Past data shows there are ten statistically different house types as far as the number and ages of children entering a particular house type are concerned. The relationships set up show how many children (not split by sex) in each of 19 individual age bands can be expected in a given number of houses. These relationships are used for all zones and all forecast years until they are updated with more recent information. The 0-5 age group concerns all children - the 6-18+ age group only L.E.A. children to be compatible with the rest of the system.

2. Births proportion (zone specific) Births are calculated by dividing the previous year's births by the existing one-year-old population (the latter includes any new house inmigrants there might be). Although the data shows the difference in the number of boy and girl births in the zone, this is not used to calculate the split between sexes of these births because it contains much random variation. This split is calculated by using the ratio of births of a specific sex to total births throughout the authority.

   The 'Clark-Davies' smoothing method tracks any change shown by the latest births proportion and extends this change into the future when forecasting for the periods ahead. (See Appendix 3)

3. Net migration proportion (zone, sex and age group specific) Net migration is calculated by multiplying the forecasted 'resident' base population by an overall migration proportion.

The overall migration proportion consists of a proportion for the existing housing stock and a proportion for last year's new houses, as it is possible that new and old houses have differing migration characteristics. This migration is a gross figure including changes of address, migration of primary school children to and from private education and to secondary schools, migration of secondary school children from primary and to and from private education and to work.

Each zone has its own characteristics of migration, as do boys and girls within each zone - for example, the age they leave school, move into private education, etc. However, certain ages have similar migration patterns and are therefore considered together. The total migration for the group is split among the component ages in proportion to their forecast gross base. The age groups are:

1 = 0-4 year olds
2 = 5 years old
3 = 6-10 year olds
4 = 11 years old
5 = 12-14 year olds
6 = 15 years old
7 = 16 years old
8 = 17 years old
9 = 18 years old

If the migration proportions differ for new and old houses the overall proportion is automatically adjusted to cater for the different migration characteristics when houses become one year old.

4. Roman Catholic Proportion This calculation is in two parts:

(a) Births Proportion (zone group specific)
This proportion is calculated by dividing Roman Catholic births by the total number of births. The most detailed figures on Roman Catholic children are the yearly parish infant baptisms, but these do not give individual figures for boys and girls. The Roman Catholic births proportion is smoothed each year by the 'Clark-Davies' method, as is the total births proportion.

(b) Roman Catholic proportion 1-18 years old (zone group specific). These proportions are also calculated using past data from the parish records and thus represent a potential maximum pupil population. Each forecast year the proportion for the J year olds equals the previous year's proportion of J-1 year olds. For each zone within the parish and each sex the same parish proportion applies

4 - UPDATING THE SYSTEM

Each year - or when an unusual change occurs in a particularly important factor - the forecasting system is updated using the latest accurate information. This chapter describes the information that is required to carry out this updating process and how it is used.

Where possible all yearly information should be on a September-August basis.

DATA PREPARATION

To ensure accuracy in the distribution of the child population, the composition of the zones given in the street index must be revised to take into account (1) new housing development, and (2) renumbering or naming.

In addition, if the child/house type relationship is being revised then the following checks must be made:

1. Only the first residents of new houses are considered, and the number of children and their ages are those at the time of moving in.
2. For new private houses the 6-18 year old children must only include those attending L. E. A. schools.

The following data is transferred to specially designed coding sheets for direct input into the computer program.

1. <u>New house completions and projected future development</u>. For each zone the following information is needed:

   (a) year when development is completed;)
   (b) council or private;) defines
   (c) house/flat or maisonette;) house
   (d) number of bedrooms;) type
   (e) number built of particular house type.)

2. <u>Births</u> For each sex, information is needed on the zone in which the mother lives.

3. <u>Migration of 0-4 year olds</u> For a child moving (1) out of the Borough, (2) into the Borough, or (3) within the Borough, information is needed on:

   (a) sex;
   (b) date of birth;
   (c) all the zones affected.

4. Migration of L.E.A. school children. For a child changing his address, or entering or leaving the school, information is needed on:

   (a) sex;
   (b) date of birth;
   (c) all the zones affected (external and internal)

   Partner infant and junior schools are regarded as the same school so that pupils leaving one to go to the other need not be recorded.

5. Roman Catholic baptisms. For each parish information is needed on the total number of infant baptisms. Several parishes have part of their area inside the borough and part outside. The baptisms must only apply to the area inside the borough. This data is provided on a January-December basis.

USE OF THE DATA

The information that has been prepared is used in two ways: to update the base population, and to update the parameters in the procedures. An illustration of the updating process is given in Figure 2.

Updating the Base Population

The population forecast one year ahead is revised by operating on the aged base (C) of last year and not the final forecast base (B). This new base is considered as the base at the start of the year. In particular:

1. Actual new births plus net migration become the new 0 year old base.
2. Net migration plus the aged base (C) become the new 1-4 year old and 6-18 year old base.
3. 'Net' migration of 5 year olds become the new 5 year old base.

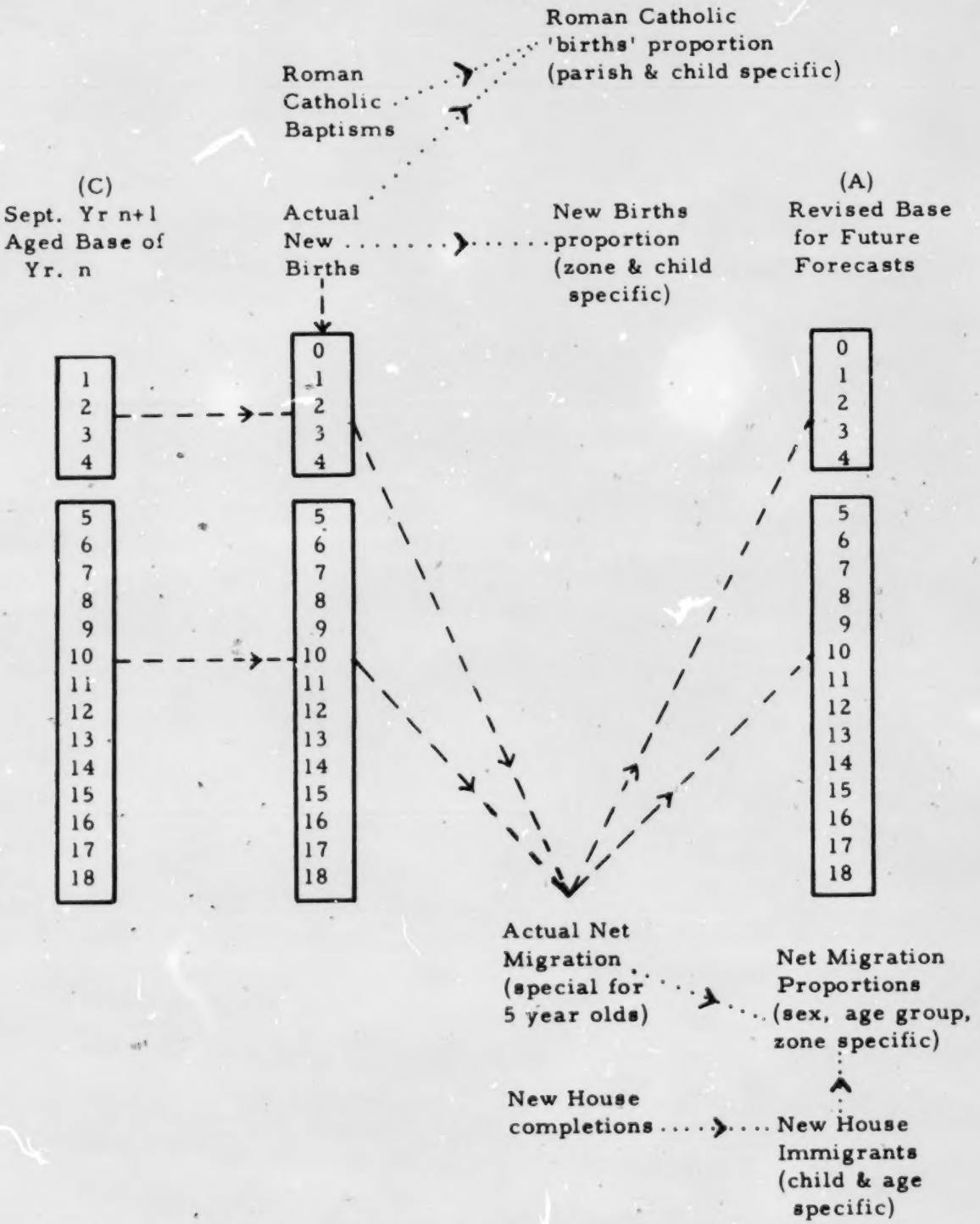
This base is the new base population (A) on which the forecasts are made for the years ahead.

UPDATING PROCEDURES

Figure 2

ZONE and SEX specific for BASE population

Time: September Year n+1


Roman Catholic 'births' proportion (parish & child specific)
Roman Catholic Baptisms
(C) Sept. Aged Yr. Yr n+1 Base of n
Actual New Births
New Births proportion (zone & child specific)
(A) Revised Base for Future Forecasts
1 2 3 4
0 1 2 3 4
5 6 7 8 9 10 11 12 13 14 15 16 17 18
Actual Net Migration (special for 5 year olds)
Net Migration Proportions (sex, age group, zone specific)
New House completions
New House Immigrants (child & age specific)

Updating the Parameters

The system itself automatically updates the parameters in the procedures using the latest information. For each procedure the updating process is as follows:

1. Child/House type relationships. Data on child inmigrants into new houses is tested against the existing data for any significant difference (see Appendix for details). The new data is added to the old distribution if no difference is found, and is substituted for the old if there is a difference. This process is in fact carried out manually.

2. New births proportion. The 1-year old base is adjusted to take into account the affect of new house completions in the last year, and the proportion of new births to this 1 year old base is calculated. Once this has been done the error in the forecasted proportion can be calculated.

3. Net migration proportions. Expected new house inmigrants are added to the base population at the start of the year to give a 'resident' population. To establish the net migration related to the stable housing stock the expected new house inmigrants are subtracted from the observed total net migration. The actual net migration proportion is calculated by dividing this adjusted net migration by the 'resident' population.

   If there is no error in the forecasted overall proportion, this figure remains as the correct proportion. If there is an error, then both the old overall proportion and the 'newish' houses proportion are revised in relation to the houses to which they apply. This calculation is done for each zone, sex and age group. For very small zones with few children over 15 years old average net migration proportions are substituted for those that might have been calculated on only 1 or 2 children. These average figures are calculated by considering migration of the last four age groups over the whole of Bromley.

4. Roman Catholic proportion. The actual Roman Catholic baptisms are divided by the overall births for the parish to give a new estimate of the Roman Catholic births proportion and the error calculated in the last forecast.

5 - EXTERNAL ZONES

A number of schools in Bromley take pupils from outside the existing borough boundaries, in particular schools that are very close to the boundary and whose catchment areas extend outside the borough. In order to take these pupils fully into account in planning its future school building programme, the education department therefore needs to know approximately what number of pupils fall into this category. The Unit has prepared a separate sub-program to be run in conjunction with the main program, which will provide forecasts of these children.

However, the exact number of children involved depends closely on the education policy of the Council concerned, since legally Bromley is not obliged to provide places for pupils outside the borough. Consequently the predictions that are made using past data may not accurately reflect the situation in the future, and must be treated with caution.

The procedures involved in the program are comparatively straightforward, and the data is collected in the same form as for the internal zones. Each year a base population is forecast for the six external zones, 5-18 year old L.E.A. children, and boys and girls. As with the births proportion, the exponential smoothing technique used is that of 'Clark-Davies' for each zone, age and sex. Thus any change in the population is tracked for the first year forecast and extended for the subsequent years' forecasts. Finally, the base is corrected each year by the in-migration and outmigration observed in the schools.

DATA SOURCES

These sources are those where at the present time the information is filed in the most accessible way. Often the effort is lessened if the data is collected throughout the year rather than in September.

1. Street Numbering and Renumbering Section of Engineer's Department.
   (a) Applications for names and addresses for new development.
   (b) Renumbering and renaming of existing houses.

2. Electoral Register.
   Postal addresses of houses in the Borough.

3. Planning Department.
   (a) Old addresses and E. D. numbers of development completed in the most recent year and its description.
   (b) Old addresses and E. D. numbers of projected yearly development up to 7 years in the future and its description.
   (c) Possibly a survey giving a description of the residents in new private houses.

4. Housing Department.
   (a) Tenancy changes in council houses - letting file.
   (b) Description of house and its residents - tenancy file.

5. Health and Welfare Department - 'Notification of Birth' cards.
   (a) Inmigration of 0-4 year old children) must be collected
   (b) Outmigration of 0-4 year old children) as it happens
   (c) Births to mothers living in Bromley.

6. L. E. A. Schools - Admissions Register.
   Sex, name, present address, admission date, deletion date of any child at the school.

7. Roman Catholic Authorities.
   Yearly infant baptisms of children under 6 years old in each of the 17 parishes covering the Borough.

8. New Private Houses - by questionnaire or survey.
   The number and ages of the residents who first occupied the house.

CHILD/HOUSE TYPE RELATIONSHIPS

COUNCIL

AGE	1 2 bedroom flats or maisonettes	2 2 bed-room houses	3 3 bedroom flats or maisonettes	4 3 bed-room houses	5 4+ bed-room dwellings
0	.17	.12	.31	.08	.13
1	.26	.10	.29	.18	.13
2	.16	.06	.18	.19	.23
3	.09	.02	.18	.19	.28
4	.06	.02	.23	.20	.26
5	.03		.11	.15	.34
6	.03	.04	.11	.20	.36
7	.01		.11	.16	.39
8	.01	.02	.04	.12	.50
9	.01	.01	.09	.12	.28
10	.01	.02	.02	.18	.31
11			.04	.11	.31
12	.01	.01	.03	.11	.18
13	.02	.04	.01	.05	.21
14		.01	.02	.06	.47
15	.01		.05	.05	.13
16		.01	.03	.01	.02
17	.01		.02	.02	.02
18					
No.	91	82	85	101	38

In each cell is shown the average number of children one house of that type will generate, i.e. council 3 bedroom house, 5-6 year old = .15, thus 100 houses means 100 x .15 = 15 children aged 5 years old. At the bottom of each column the sample size of houses surveyed is given for updating purposes.

CHILD/HOUSE TYPE RELATIONSHIPS

PRIVATE

AGE	6 2 bedroom flats or maisonettes	7 2 bed-room houses	8 3 bedroom flats or maisonettes	9 3 bed-room houses	10 4+ bed-room dwellings
0		.11	.13	.10	.11
1	.02	.02	.06	.14	.14
2	.02	.02	.06	.10	.10
3	.04	.02	.06	.10	.08
4			.13	.11	.10
5				.05	.04
6		.02	.06	.04	.11
7		.02	.06	.05	.05
8			.19	.02	.08
9		.02		.04	.01
10			.13	.04	.08
11		.02	.06	.02	.01
12			.06	.01	.05
13			.06		.01
14			.06	.01	.04
15		.02	.06		.01
16			.06	.01	.04
17		.02		.03	.03
18					.03
No.	48	47	16	148	79

In each cell is shown the average number of children one house of that type will generate, i.e. private 4 bedroom dwelling 10-11 year old = .08, thus 100 houses means 100 x .08 = 8 children aged 10 years old. At the bottom of each column the sample size of houses surveyed is given for updating purposes.

UPDATING HOUSING RELATIONSHIPS

The following manual procedure tests whether new data on children moving into new dwellings is consistent with the existing relationship. The statistical test used is that of Chi-squared. * The new data, of course, should come from as large a sample as possible, i.e. enough houses to generate at least twenty children in each type of house.

Take 3 bedroom private houses as an example. See Figure 5 for the effect of the following calculations.

1. Calculate expected numbers of children from the existing relationship.
2. List actual numbers of children in the new dwellings. (100 in example).
3. Equalise the sample size to the number of children expected if 148 new dwellings were observed (column 2 x $\frac{148}{100}$).
4. For Chi-squared test each observed division has to have at least 5 observations. Combine the readings in column 3 to give grouped divisions of more than 5 - observed distribution (0).
5. Combine similarly the readings in column 1 to give the expected distribution (E).
6. Calculate the difference between the distributions for each division and square it.
7. Divide each number in column 6 by the respective expected value (E), and sum for a total.
8. Compare the total with the appropriate Chi-squared value from the table. **

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* See 'Statistical Methods for Technologists' by Paradine and Rivett for a short discussion of this test.

** Chi-squared tables can be found in 'Cambridge Elementary Statistical Tables' by Lindley and Miller, C.U.P.

9. Set up the new child distribution which is, either (a) the summation of the old and new sample distributions if the value of Chi-squared is insignificant.

or (b) the new sample distribution if the value of Chi-squared is significant.

10. Convert the distribution to give the proportions of children of each age expected in one house.

UPDATING HOUSING RELATIONSHIPS

Figure 5

Age	3 bedroom houses	(1) Children expected by first distribution	(2) New Children Actual	(3) Equalise sample size	(4) Set up divisions of ≥5 (0)	(5) Combine Column 1 similarly (E)	(6) Difference cols (5-4)^2 $(0-E)^2$	(7) $\frac{(O-E)^2}{E}$	(9) New Child distribution (1) + (2)	(10) Child Proportions Col. $\frac{(9)}{248}$
0	.10	15	10	14.8	14.8	15	.04	0	25	.10
1	.14	21	12	17.8	17.8	21	10.1	.48	33	.13
2	.10	15	11	16.4	16.4	15	2.0	.13	26	.10
3	.10	15	13	19.2	19.2	15	17.7	1.18	28	.11
4	.11	16	12	17.8	17.8	16	3.2	.20	28	.11
5	.05	7	6	8.9	8.9	7	3.6	.51	13	.05
6	.04	6	4	5.9	5.9	6	3.6	.60	10	.04
7	.05	7	6	8.9	8.9	7	3.6	.51	13	.05
8	.02	3	1	1.5					4	.02
9	.04	6	2	3.0	7.5	15	56.3	3.75	8	.03
10	.04	6	2	3.0					8	.03
11	.02	3	3	4.4	5.9	4	3.6	.90	6	.02
12	.01	1	1	1.5					2	.01
13			1	1.5					1	
14	.01	1	2	3.0	7.5	6	2.3	.38	3	.01
15			1	1.5					1	
16	.01	1							1	
17	.03	4	1	1.5					5	.02
18										
Sample Size	148	148	100	(148)				$\sum$ = 8.64	248	248

(8) n = 11 divisions, ∴ degrees of freedom = n - 1 = 10
Chi^2 at ± 5% is 18.31
± 2.5% is 20.48

As our value of Chi^2 is less than that from the tables at the considered probability levels, the conclusion is, there is no significant difference in the two distributions.

The new distribution (9) is the summation of the old and the new sample distributions.

APPENDIX 3

'CLARK-DAVIES' FORECASTING METHOD

This simple exponential smoothing technique was originally developed for stock control. However, its error tracking properties and minimal storage needs make it very useful in systems where many items have to be forecast by computer.

Essentially a model for data which is constant except for random noise, it has a high tracking ability one period ahead. Also the choice of β' affects the extension of the latest correction term for forecasting several periods ahead.

The mathematics of the method are:
at time (t) and latest observed error E_t

1. Forecast (F_{t+1}) one period ahead $\quad F_{t+1} = F_t + C_{t+1}$

$$C_{t+1} = \beta C_t + \alpha E_t$$

Thus $F_{t+1} = F_t + \alpha (E_t + \beta E_{t-1} + \beta^2 E_{t-2} + \text{----})$

The correction factor C_{t+1} is seen as a function of all the observed forecast errors in which the errors are smoothed by two distinct smoothing constants.

2. Forecast F_{t+2}, etc., i.e. forecasting several periods ahead

Assume $E_{t+1} = E_{t+2}$ and so on $= 0$ then

$$F_{t+2} = F_{t+1} + (\beta')C_{t+1}$$

$$F_{t+3} = F_{t+2} + (\beta')^2 C_{t+1} \quad \text{and so on.}$$

Many runs have been computed on specially designed data to test the sensitivity of α, β and β'. The system is set up with three sets of these parameters such that overall, errors are minimised although, for any one zone the parameters may not be the best.

Thus:				
R.C. proportions	$\alpha = .59$	$\beta = .67$	$\beta' =$	.85
Births proportion	$\alpha = .3$	$\beta = .7$	$\beta' =$	.4
External zones	$\alpha = .46$	$\beta = .56$	$\beta' =$	.75